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Molluscan community composition and richness in four high-elevation Idaho streams includes an exotic taxon

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Abstract: Effective conservation requires that natural resource managers understand the diversity of organisms within a jurisdictional unit. Too frequently, conservation priorities are determined without adequate biological information, leading to inefficient use of very limited resources. We investigated molluscan community composition and richness within the eastern portion of the Sawtooth National Recreation Area (*i.e.*, management unit) in Custer County, Idaho, USA to (1) identify populations of non-native species, if present, (2) acquire baseline information on the distribution, relative abundance, and diversity of molluscs in this high-elevation ecosystem, and (3) provide resource managers with useful information with which to inform conservation priority-setting. We found a rich molluscan community comprised of 19 species from 11 genera and 7 families. We also documented a single population of the non-native species *Radix auricularia* Linnaeus, 1758 from samples at Alturas Lake. Management of the very popular, eastern portion of the Sawtooth National Recreation Area should include public outreach regarding invasive species, importance of proper cleaning of boats and fishing gear, and importance of native invertebrates to healthy, functioning ecosystems.

Key words: diversity, non-native, *Margaritifera*, headwater, Salmon River

Effective conservation of molluscs requires that natural resource managers understand the taxonomy of the species within their jurisdiction, the richness of taxa within a given area, and the status of those taxa over time (Lysne *et al.* 2008). In Idaho, freshwater molluscs have received considerable recent attention due to the endangered status of some species (Lysne and Koetsier 2006, Richards *et al.* 2006, Myler *et al.* 2007), descriptions of new species (Hershler *et al.* 2006), taxonomic revisions of others (Hershler and Liu 2004, Wethington and Lydeard 2007), concern with regard to non-native species (Richards *et al.* 2001, Lysne and Koetsier 2008, Hershler *et al.* 2010), and efforts to document the richness of species state-wide (Lysne and Clark 2009). Of particular concern to resources managers in Idaho is the presence and status of non-native freshwater mollusc invasions. Of the 117 putative freshwater mollusc taxa in Idaho, as many as 15 are non-native species (Frest and Johannes 2000) and others are likely to become established within the next decade (*e.g.*, species of *Dreissena* Beneden, 1835). Our study investigated four high-elevation lakes and tributaries to the upper Salmon River within the Sawtooth National Recreation Area (SNRA) to describe the freshwater molluscan community, estimate abundance, document the presence of non-native species, and determine the distribution of non-native species. The lakes and rivers of the SNRA are popular with recreationists and sportsmen, and the probability of invasions of exotics was considered to be high.

MATERIALS AND METHODS

Study area

The SNRA lies within the Sawtooth National Forest in south-central Idaho (Fig. 1) and is in the molluscan zoogeographical region known as the Western American Division (Burch 1989). Annual precipitation ranges between 51 and 112 cm over the period of record from 1978 to 2009 (http://www.wcc.nrcs.usda.gov/cgibin/snotel/). We limited our work to four high-elevation lakes, and their inlet and outlet creeks (hereafter known as "sites"), on the east side of the SNRA, south of the town of Stanley, Idaho. The sites—Alturas, Petitt, Stanley, and Redfish Lakes—range in elevation from 1,981 m to 2,133 m and are each fed by 1st order creeks originating from the Sawtooth Mountain Range. These tributaries to the Salmon River exhibit a classic snowmelt hydrograph (Allan 1995) characterized by high flows in May and June and low flows from late fall to mid-winter. We observed maximum mean summer temperatures between 13 and 25 °C and very low conductivities (data available on request to SJL). Daily mean air temperature is consistently below freezing from mid-October to mid-May (http://www.wcc.nrcs.usda.gov/nwcc/view), resulting in extensive ice cover annually and a relatively short growing season. Thus, each lake and creek is considered oligotrophic relative to waterbodies in Idaho at lower elevations.

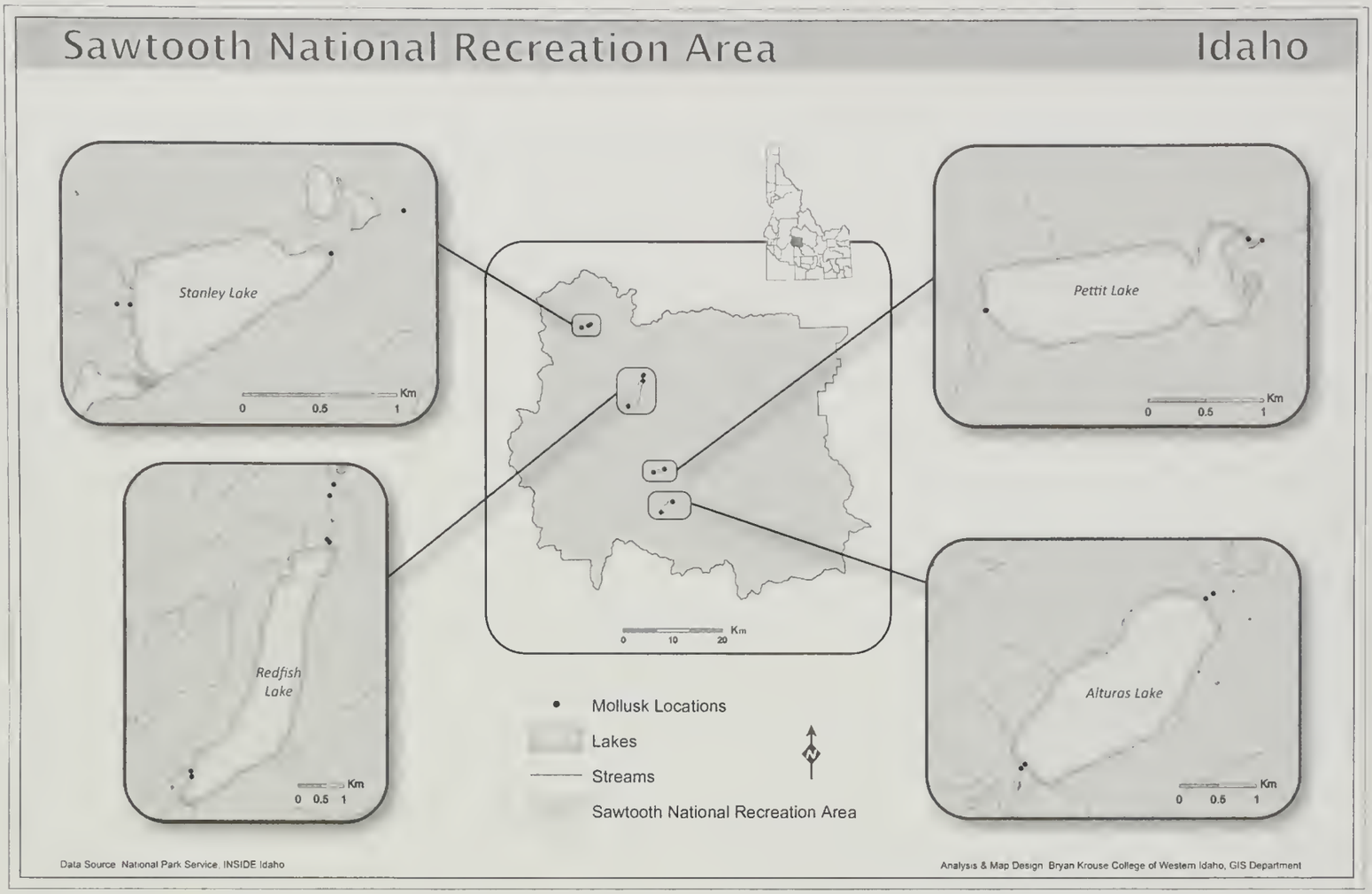

Figure 1. Map of the Sawtooth National Recreation Area showing the location of lakes surveyed and samples collected.

Field sampling

All sites were surveyed during the fall of 2005 by U.S. Forest Service biologists. Both qualitative (timed searches) and quantitative (systematic sampling with multiple random starts) methods were used to capitalize on the benefits of different survey techniques. Because habitat types in a survey location can be visited with reasonable effort, qualitative surveys can be useful for documenting species presence. Quantitative sampling, by contrast, is preferable to estimate abundance and associated variances (Strayer and Smith 2003) but may not detect rare species in micro-habitats missed by systematic sampling.

During qualitative surveys, biologists visually searched for molluscs using benthic viewers in wadeable portions of a lake or creek (*i.e.*, <1 m depth). In creeks, all habitat types were surveyed, non-randomly, within 300 m of the inlet and outlet of each lake for three person-hours. Methods were similar between sites but were limited in lakes to the wadeable shoreline on both sides of the inlet and outlet; survey time was one person-hour. Representative specimens of each unique taxa (with the exception of *Margaritifera falcata* Gould, 1850) were collected and preserved in 70% ETOH. Multiple specimens were collected for some taxa as all individuals could not be readily identified in the field. When *M. falcata* were encountered, researchers measured each individual to the nearest mm and returned the specimen to its place of origin. No attempt was made to collect all individuals observed, or to quantify species abundance or density via qualitative surveys. Qualitative surveys contributed to estimates of species richness only.

Biologists conducted quantitative, systematic sampling on the outlet creeks at Alturas, Redfish, and Stanley Lakes only. Due to resource limitations, Petitt L. was not included in systematic sampling and was thus excluded from all analyses based on systematic samples. A systematic survey design was used at each site following Strayer and Smith (2003). Systematic surveys are efficient for rare or clustered populations and multiple random starts help provide accurate estimates of variance (Christman 2000). Biologists delineated a 100 m reach of each creek as near the mouth of the outlet as

possible subject to safety concerns such as extreme flow velocities, stream gradients, and plunge pools. A grid was superimposed over the 100 m reach and coordinates were generated for at least three random starts. Subsequent systematic samples were collected at the y^{th} interval following Strayer and Smith (2003). Each random start and resulting samples constituted an experimental unit. Biologists sampled a minimum of 50 quadrats at each site using benthic viewers. Quadrats were constructed of PVC piping and were either 1 m^2 or 0.25 m^2 depending on the estimated density of molluscs determined during pilot studies conducted *a priori*. At Alturas and Redfish Lakes, researchers used a 1 m^2 quadrat and at Stanley L., where mollusc density was relatively high, a smaller, 0.25 m^2quadrat, was used. We acknowledge that the use of different quadrat sizes complicates our comparisons but believe that a simple scaling factor allows comparisons and violates no assumptions. Estimates of biomass and diversity are derived from quantitative sampling only.

For each quadrat, biologists visually inspected the benthos and removed any benthic substrate greater than *ca.* 30 mm in diameter for inspection of all surfaces. A quadrat was considered "surveyed" when all substrates >30 mm were removed and the quadrat had been thoroughly examined. Researchers did not use a suction dredge or excavate embedded cobbles or boulders, and not all individuals present at any given site were collected, thus our findings are likely to be underestimates for several taxa including the limpets and fingernail clams. All samples were preserved in 70% ETOH with the exception of *Margaritifera falcata* which were measured to the nearest mm and returned to their place of origin.

Laboratory processing

U.S. Forest Service biologists shipped the preserved specimens to the College of Western Idaho for enumeration, identification, analysis, and preparation for museum curation. All individuals of each taxon (with the exception of *Margaritifera falcata*) were grouped together after identification and weighed to the nearest 0.001 g. We used wet-weight for biomass calculations. Molluscs were removed from vials, blotted dry, and then weighed; we did not remove soft tissue from shells. For *M. falcata*, we used unpublished length/wet-weight regressions to estimate biomass. All samples are available for reference or further study at the Orma J. Smith Museum of Natural History (http://www.collegeofidaho.edu/campus/). All individuals from each site were identified following Burch (1989) and Wethington and Lydeard (2007) and nomenclature followed Turgeon *et al.* (1998).

Data analysis

We calculated a single species richness value for each of the four sites by enumerating unique taxa. We did not differentiate between richness in the lake versus richness at inlet or outlet creeks. We also calculated the Simpson's Diversity Index (D) for each site and compared these values descriptively across sites. We used only samples from the outlet creeks where systematic sampling was conducted for biomass and D comparisons, thus we did not use Petitt L. data in these analyses. Biomass (grams/m^2) for all taxa collected at each site was summed and compared across sites using one-way ANOVA. We multiplied biomass values for Stanley L. samples by a factor of four before comparisons were made due to the smaller quadrat size used in Stanley L. Creek (*i.e.*, 0.25 m^2 vs. 1 m^2) and our need to standardize sampling units for statistical purposes. We constructed species importance curves following Lysne and Clark (2009). Species importance curves represent dominant taxa based on abundance or, in our case, biomass and assume ecological importance based on that dominance. Curves in our study are based on biomass and were created for the entire SNRA and for each site then compared descriptively across sites.

RESULTS

We collected and identified 2,366 freshwater molluscs from 514 samples collected at four alpine lakes. Species richness at the SNRA consists of 19 species from 11 genera and 7 families (Table 1). Though only one population was observed, abundance of *Margaritifera falcata* dominated that molluscan fauna (Fig. 2). Biomass was not different within sites surveyed but differed significantly across sites ($\alpha = 0.05$; $df = 2, 187$; $P < 0.001$; Table 2). The greatest value for biomass was observed at Stanley L. where *M. falcata* was most abundant (Fig. 3) by two orders of magnitude. At Alturas and Redfish Lakes, the molluscan fauna was dominated by *Radix auricularia* Linnaeus, 1758 and *Stagnicola emarginata* Say, 1821, respectively (Fig. 3). Species richness was greatest at Stanley L. followed by Alturas and Redfish Lakes (Table 3). Species diversity was highest at Redfish L. ($D = 2.16$) relative to Stanley L. ($D = 3.36 \times 10^{-4}$) and Alturas L. ($D = 2.06 \times 10^{-4}$). We documented a single, extant population of non-native species in the SNRA. We collected 144 *R. auricularia* from 38 samples at Alturas L. We also collected shells of the non-native *Planorbella duryi* Wetherby, 1879 in Stanley L. but failed to document an extant population there.

DISCUSSION

We conducted a survey of four alpine lakes in the Sawtooth National Recreation Area (SNRA) to identify mollusc populations of management concern and to describe the mollusc community in this remote, high-elevation ecosystem. Understanding the diversity, distribution, and

Table 1. Molluscs present during sampling in the Sawtooth National Recreation Area, Custer County, Idaho. Data show presence related to lakes as well as conservation status. Voucher specimens of each taxon are kept at the Smith Museum of Natural History. Abbreviations: A, Alturas; P, Pettit; R, Redfish; S, Stanley. Rankings are from NatureServe (2010): G1/S1, critically imperiled; G2/S2, imperiled; G3/S3, vulnerable; G4/S4, apparently secure; G5/S5, secure; SNR, state not ranked; EXO, exotic/introduced; NA, no ranking available. *Collected as shell only.

Family	Genus	Species	Authority	Lake	G rank	S rank
Gastropods						
Ancylidae	*Ferrissia*	*rivularis*	Say, 1817	S	G5	SNR
Lymnaeidae	*Fossaria*	*obrussa**	Say, 1825	A	G5	SNR
Lymnaeidae	*Fossaria*	sp.	Westerlund, 1885	S	NA	NA
Lymnaeidae	*Pseudosuccinea*	*columella**	Say, 1817	A	G5	SNR
Lymnaeidae	*Radix*	*auricularia*	Linnaeus, 1758	A	G5	EXO
Lymnaeidae	*Stagnicola*	*emarginata*	Say, 1821	A,P,R	G5	NA
Physidae	*Physa*	*gyrina*	Say, 1821	A,P,R,S	G5	SNR
Planorbidae	*Gyraulus*	*circumstriatus*	Tryon, 1866	A,P,R,S	G5	SNR
Planorbidae	*Gyraulus*	*parvus*	Say, 1817	A,P,R,S	G5	SNR
Planorbidae	*Gyraulus*	*deflectus*	Say, 1824	S	G5	SNR
Planorbidae	*Planorbella*	*ammon*	Gould, 1855	S	NA	NA
Planorbidae	*Planorbella*	*duryi**	Wetherby, 1879	S	G5	EXO
Planorbidae	*Planorbella*	sp.	Haldeman, 1842	S	NA	NA
Planorbidae	*Planorbella*	*subcrenata*	Carpenter, 1857	S	G5	SNR
Valvatidae	*Valvata*	*humeralis**	Say, 1829	R,S	G5	SNR
Bivalves						
Margaritiferidae	*Margaritifera*	*falcata*	Gould, 1850	A,R,S	G4	SNR
Sphaeriidae	*Pisidium*	*casertanum*	Poli, 1791	A,P,R,S	G5	SNR
Sphaeriidae	*Pisidium*	*conventus*	Clessin, 1817	S	G5	SNR
Sphaeriidae	*Pisidium*	*insigne*	Gabb, 1868	S	G5	SNR

trend of biological communities is a prerequisite to setting conservations priorities (Lysne *et al.* 2008). Our understanding of the distribution and abundance of mollusc communities, including species of management concern, has benefitted in recent years from the efforts of scientists across North America (Lysne and Clark 2009, Dillon *et al.* 2010, Evans and Ray 2010).

Of primary interest are the potential presence, distribution, and abundance of non-native species within the SNRA management unit. The SNRA supports considerable recreational boating, and the spread of non-native species via recreational boaters is of concern. The state of Idaho has recently increased awareness and enforcement of nuisance aquatic species violations targeting specifically members of the freshwater genus *Dreissena* [http://www.idahoag.us/Categories/Environment/InvasiveSpeciesCouncil/index]. Our survey of the SNRA, fortunately, failed to find any non-native bivalve molluscs (*e.g.*, *Dreissena* sp. or *Corbicula* sp. von Muhlfeld, 1811) but did document an extant population of *Radix auricularia* in Alturas L. This non-native gastropod was, in fact, the most abundant member of the molluscan community at Alturas L. While *R. auricularia* populations are not uncommon in Idaho, the relative abundance of this species in Alturas L. should be of concern to resources managers. It is of ecological interest, however, that *R. auricularia* was found only in one site.

Also of interest is that certain taxa were found exclusively at either Stanley L. in the north of the SNRA or at Alturas L. in the south of the SNRA. Neither Redfish nor Pettit Lakes contained any taxa that were unique to those systems. This suggests two molluscan faunas, one in the north and one in the south of the SNRA, mixing together in middle-latitude sites. From our collections, species belonging to the family Planorbidae Rafinesque, 1815 are distributed in the northern portions of the SNRA and those of the family Lymnaeidae Rafinesque, 1815 are distributed primarily in the south. Elucidation of this distribution difference will await a more detailed study.

A single population of *Margaritifera falcata* was observed in Stanley L. Creek. A single individual *M. falcata* was observed at both Alturas and Redfish Lakes during qualitative sampling, but was not picked up during systematic sampling. Mussel beds frequently display highly clumped distributions (Strayer and Smith 2003), so it is possible that active beds were missed due to our systematic sampling design. Indeed, beds have been observed downstream of the experimental reach in both Redfish and Alturas L. Creeks (SJL, pers. obs.). Is it because of *M. falcata* that molluscan biomass in Stanley L. is nearly two

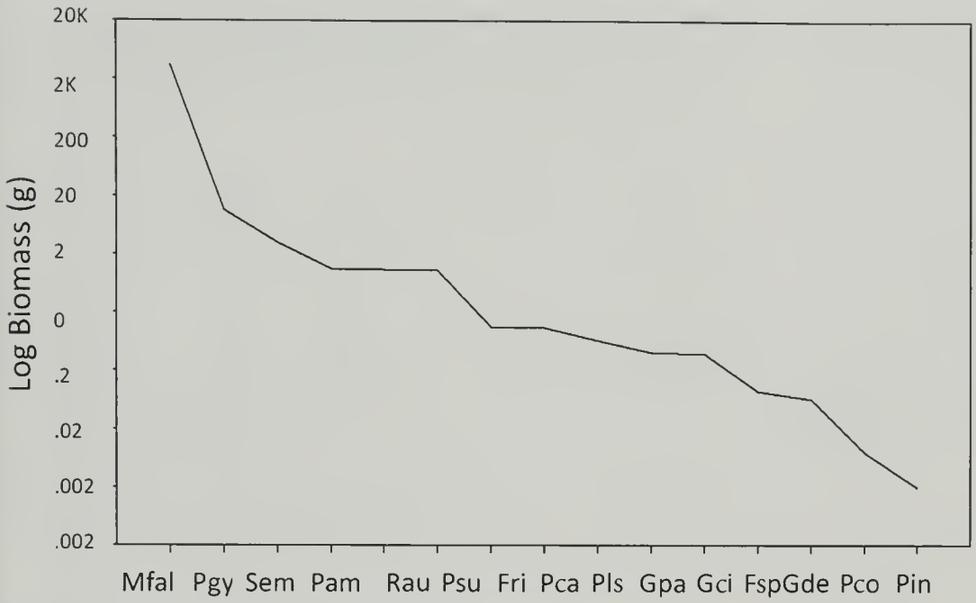

Figure 2. Species importance curve for molluscs in the SNRA. Abbreviations are: **M**argaritifera **fal**cata, **P**hysa **gy**rina, **S**tagnicola **em**arginata, **P**lanorbella **am**mon, **R**adix **au**ricularia, **P**lanorbella **su**bcrenata, **F**errissia **ri**vularis, **P**isidium **ca**sertanum, **P**lanorbella **sp.**, **G**yraulus **p**arvus, **G**yraulus **ci**rcumstriatus, **F**ossaria **sp.**, **G**yraulus **de**flectus, **P**isidium **co**nventus, and **P**isidium **in**signe.

Table 2. Analysis of variance of mean biomass for molluscs within and between sites. No significant differences were detected within the three sites but differences between sites were significant at $\alpha = 0.05$.

Site	*df*	*F*	*P*-value
Within groups			
Alturas Lake	142	3.06	0.09
Redfish Lake	78	3.11	0.64
Stanley Lake	244	2.25	0.06
Between groups	2	3.01	< 0.001

orders of magnitude greater than in either Alturas or Redfish Lakes? Does the presence of abundant *M. falcata* also explain why species richness is nearly double at Stanley L. relative to all other sites in our study? Vaughn and Spooner (2006) demonstrated that macroinvertebrate densities are significantly greater in stream segments where mussels are found relative to stream segments without mussels. They suggest that nutrient enrichment via biodeposits, or pseudofeces, support greater productivity in mussel beds and thus influence macroinvertebrate assemblages. Our results are consistent with their conclusions and demonstrate greater species richness and biomass, even when excluding mussel biomass, in streams with mussels compared to without.

We were surprised to find this high-elevation ecosystem is so speciose. Clarke *et al.* (2008) reviewed world-wide studies of macroinvertebrate richness and generally found that richness was greater in mid-order streams. Vannote *et al.* (1980), of course, proposed the River Continuum Concept around this phenomenon. The streams in our study, however, were all 1st or 2nd order and at high elevations. Similar work in Idaho has found comparable values for molluscan richness (Lysne and Clark 2009) but the composition of species, the habitat, and stream order differed greatly. For example, three molluscan families contributed disproportionately to the high richness value for the SNRA—Lymnaeidae, Planorbidae, and Sphaeriidae Deshayes, 1855—and the Lymnaeidae were the most important in two of four sites (Figs. 5, 6). Most studies of species richness, however, emphasize EPT taxa (*i.e.*, the orders Ephemoptera, Plecoptera, and Trichoptera), and if molluscs are included at all, they are determined only to the taxonomic level of class. Hieber *et al.* (2005) investigated community composition in alpine streams in Finland and found that collector/gatherers dominated the outlets of alpine lakes. This study too considered primarily EPT taxa; only a single mollusc was reported in all collections (Hieber *et al.* 2005; Appendix 1). However, we can compare their information on functional feeding groups to our molluscan assemblage. In our study, sites were dominated by scrapers, not collector/gatherers, with the exception of Stanley Lake where the filter-feeding *Margaritifera falcata* dominated the community. Harding (1994) conducted a much broader study of community composition in high-elevation lakes in New Zealand. While his work provides the best information for comparisons of richness, it is a very different ecological system, but with similar abiotic parameters. Harding investigated 20 alpine lake outlets and found that richness was significantly lower at the highest elevation lakes. He also found that the functional feeding groups at higher elevation sites were dominated by collector/gatherers and filter feeders. Molluscs were not abundant in alpine lakes in his study until lower elevations, *ca.* 200 to 500 meters (Harding 1994). Our results differ from both Hieber *et al.* (2005) and Harding (1994) and are interesting because, although we did not sample for all stream taxa, we found a diverse community of filterer and scraper functional feeding groups.

In summary, the Sawtooth National Recreation Area has a relatively rich molluscan community including a large population of *Margaritifera falcata* and at least one viable population of non-native molluscs. There was no evidence of the highly invasive *Potamopyrgus antipodarum* Gray, 1843 or

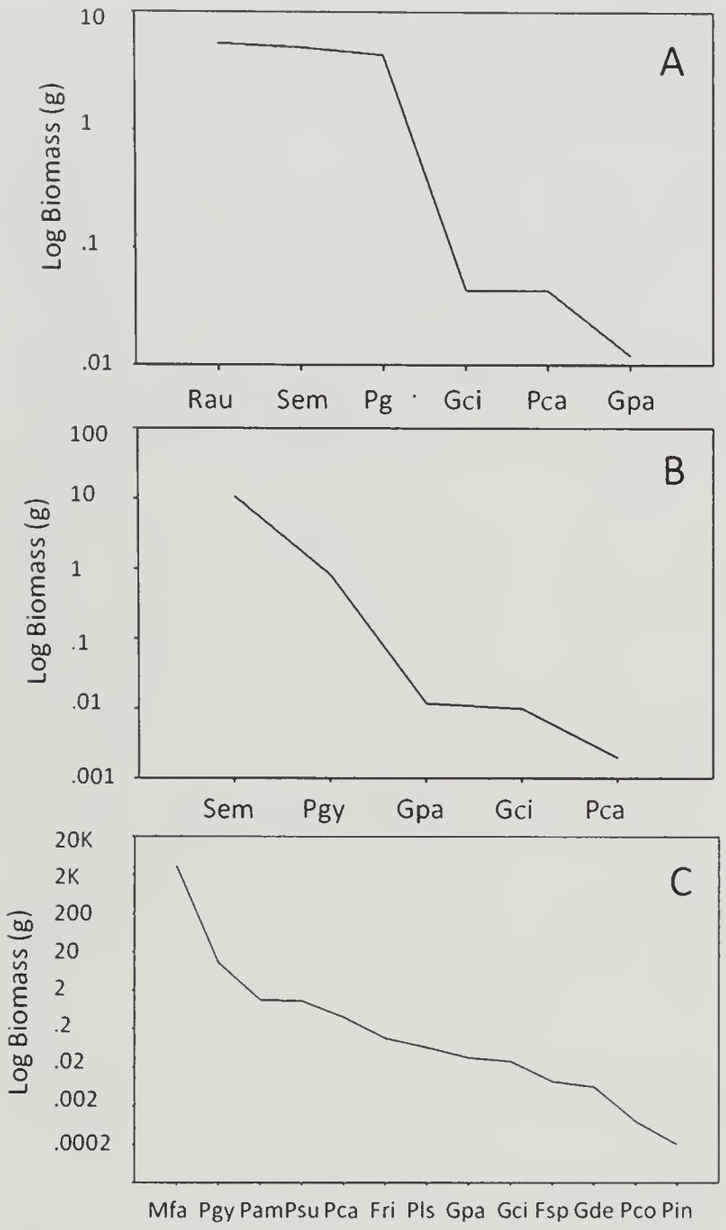

Figure 3. Species importance curve for molluscs collected live in Alturas (A), Redfish (B), and Stanley L. (C) sites. Abbreviations are: **F**errissia **ri**vularis, **F**ossaria **sp.**, **G**yraulus **ci**rcumstriatus, **G**yraulus **de**flectus, **G**yraulus **pa**rvus, **M**argaritifera **fa**lcata, **P**hysa **gy**rina, **Pi**sidium **co**nventus, **Pi**sidium **in**signe, **P**lanorbella **sp.**, **P**lanorbella **am**mon, **P**lanorbella **su**bcrenata, **Pi**sidium **ca**sertanum, **R**adix **au**ricularia, and **S**tagnicola **em**arginata.

Dreissena sp. Natural resource managers, however, should monitor the population of *Radix auricularia* at Alturas L. and work to prevent the spread of this, and other, nuisance species to alpine lakes in this relatively pristine ecosystem. Management should also include public outreach regarding invasive species, the importance of properly cleaning boats and fishing gear, and the importance of native invertebrates to a healthy, functioning ecosystem. Finally, the distribution of *M. falcata* in the SNRA is uncertain and we suggest future workers learn why this species is apparently restricted to Stanley L. Creek or, alternatively, why it exists at such low densities as to avoid detection at Alturas and Redfish L. Creeks.

Table 3. Molluscan species richness, diversity (Simpson's *D*), and estimated biomass (g/m^2) at each site compared to lake area. Notice that biomass and diversity values for Pettit Lake are excluded (NA); see methods for explanation.

Location	Lake area (km^2)	Biomass (g/m^2)	Richness	Diversity
SNRA		35	19	3.41
Alturas Lake	3.4	0.097	9	$2.06*10^{-4}$
Redfish Lake	6.1	0.129	7	2.16
Stanley Lake	0.7	68.54	15	$3.36*10^{-4}$
Pettit Lake	1.6	NA	5	NA

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